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# RESPONSES OF GROUP-HOUSED NEONATAL CHICKS TO POSTHATCH HOLDING ENVIRONMENT

H. Xin, J. D. Harmon

**ABSTRACT.** The posthatch energetics of neonatal chicks exposed to a variety of environmental conditions was investigated. Specifically, moisture production (MP), sensible heat production (SHP), total heat production (THP), respiratory quotient (RQ), and body mass loss (BML) of breeder chicks during a 50 h posthatch holding period in shipping containers at the ambient temperatures of 20, 25, 30, and 35°C with the concomitant relative humidity of 40%, 30%, 22%, and 17%, respectively, were determined. The average responses of the chicks under these environmental conditions were respectively, 3.8, 4.0, 4.1, and 4.6 g·(kg·h)<sup>-1</sup> MP; 7.8, 6.4, 5.7, and 5.2 W·kg<sup>-1</sup> SHP; and 10.3, 9.1, 8.5, and 8.4 W·kg<sup>-1</sup> THP. RQ was independent of the temperature ( $P = 0.59$ ) and averaged 0.75. BML increased with temperature ( $P < 0.01$ ) and averaged 5.3, 5.7, 5.9, and 6.3 g·chick<sup>-1</sup>, or 13.5%, 14.4%, 14.9%, and 15.9% of the initial body mass, respectively. Chick mortalities at 20°C and 25°C (1.09% and 0.71%) were higher than those at 30°C and 35°C (0.28% and 0.33%) ( $P < 0.01$ ). Based on the criteria of least thermoregulatory efforts and mortality, the thermal neutrality for the unfed, group-housed neonatal chicks was between 30°C and 32°C. Moreover, the metabolic rate of the fasting chicks at thermal neutrality, 77 kcal·day<sup>-1</sup>/kg<sup>0.75</sup> of this study agreed well with the literature value of 70 kcal·day<sup>-1</sup>/kg<sup>0.75</sup> for fasting homeotherms. This study provides unique data for the design and operation of ventilation and environmental control systems during transportation of baby chicks.

**Keywords.** Heat production, Moisture production, Chicks, Posthatch, Transport, Temperature.

One critical issue in shipping breeder chicks is proper ventilation rate and thermal conditions during the journey; however, information on the chick energetics during this posthatch period is meager, making it difficult to determine the required in-transit ventilation rates for the chicks. Compared with chicks in the production facilities, chicks in transit are often subjected to an extended period of nutritional deficiency, water deprivation, and suboptimal environmental conditions (Xin and Rieger, 1995). Consequently, it is impractical to use the limited energetics data on day-old chicks provided *ad-libitum* access to feed (ASAE Standards, 1994; Zulovich et al., 1987) in the design or operation of ventilation systems for chick transportation.

Muller (1985) suggested the minimum in-transit ventilation rate for baby chicks of 0.68 m<sup>3</sup>·h<sup>-1</sup>·kg<sup>-1</sup> (0.18 CFM·lb<sup>-1</sup>) during flight and 1.68 m<sup>3</sup>·h<sup>-1</sup>·kg<sup>-1</sup> (0.45 CFM·lb<sup>-1</sup>) on the ground. These suggested values

were based on the assumption that the chicks were in a state of maintenance with a heat production rate of  $HP_m = 7 \cdot M^{0.75}$ , where  $HP_m$  is in W·chick<sup>-1</sup> and  $M$  is chick body mass in kg. But, the validity of such an assumption is very much questionable for posthatch-fasting chicks. For instance,  $HP_m$  of a 40 g chick at 30°C temperature is 0.63 W·chick<sup>-1</sup> (15.8 W·kg<sup>-1</sup>); whereas, Van der Hel et al. (1990) reported that the same size chicks group-housed during a 24 h posthatch period at 31 to 36°C had a  $HP$  of only 0.35 W·chick<sup>-1</sup> (8.8 W·kg<sup>-1</sup>). Mission (1975) also found that unfed, day-old chicks (35 g) kept in groups of 20 had a  $HP$  of 0.26 W·chick<sup>-1</sup> (7.4 W·kg<sup>-1</sup>) at 30°C, and 0.52 W·chick<sup>-1</sup> (14.9 W·kg<sup>-1</sup>) at 20°C. Thus, it seems that application of  $HP_m$  to in-transit ventilation design likely leads to over-ventilation of the chicks. Over-ventilation during air transport is counterproductive because it not only costs extra energy, but more importantly causes a drier environment around the chicks and increases chick dehydration. Xin and Rieger (1995) found that relative humidity inside the aircraft cargo compartments was 10 to 20% most of the time.

Although the studies of Van der Hel et al. (1990) and Mission (1976) may offer more realistic, posthatch heat production rate of neonatal chicks, data were lacking as to moisture production (MP) and sensible heat production (SHP) of the chicks. Furthermore, the energetic characteristics of the chicks may well be influenced by their genetics and housing conditions such as stocking density and bedding materials used during commercial shipment operation. Hence, the objective of this study was to determine the energetic responses of neonatal chicks during a posthatch-holding period under the representative commercial operation conditions. Specifically, MP, SHP, total heat production (THP), respiratory quotient (RQ), and

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Article was submitted for publication in February 1996; reviewed and approved for publication by the Structures and Environment Div. of ASAE in August 1996.

This is Journal Paper No. J-16736 of the Iowa Agriculture and Home Economics Experiment Station, Iowa State University, Project No. 3355. Funding for this study was provided in part by Hy-Line International. Mention of company or product names is for presentation clarity and does not imply endorsement by the authors or Iowa State University; nor exclusion of any other products that also may be suitable for the application.

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body mass change of group-housed layer breeder chicks in shipping containers were measured during a 50 h posthatch period at the air temperatures of 20, 25, 30, and 35°C.

## MATERIALS AND METHODS

### CHICKS AND TEMPERATURE TREATMENTS

Hy-Line TK male breeder chicks with an initial body mass of approximately 40 g were used in this study. The chicks were group-housed in the commercial, excelsior-padded cardboard shipping containers (61L × 46W × 18H cm), with 22 chicks/compartiment or 88 chicks/container. Within 5 h after hatching, 2,112 chicks in 24 containers were delivered to our ISU research laboratory in Ames from the hatchery (Dallas Center, Iowa) 50 km away. Upon arrival, the chicks were weighed and randomly assigned to the temperature treatments of 20, 25, 30, or 35°C ( $\pm 0.3^\circ\text{C}$ ), 528 chicks in six containers per treatment. The chick containers were evenly spaced on the floor of the calorimeter chambers (described below). During the treatment period, the original cardboard container lids were replaced with poultry netting covers to ensure proper air exchange between the chicks and the chamber environment. Relative humidity (RH) for the temperature regimens was 40%, 30%, 22%, and 17% ( $\pm 3\%$ ), respectively, (with a similar dewpoint temperature of approximately 6.0°C). Selection of the low RH levels in this study was based on the previous measurements of transport conditions (Xin and Rieger, 1995). No feed or

water was provided during the 50 h trial period. Continuous lighting was provided at approximately 30 lux intensity. Four replicates were conducted for each temperature treatment, and a complete random block experimental design was used.

### INDIRECT ANIMAL CALORIMETRY SYSTEM

Figure 1 shows the schematic of the ISU open-circuit, positive pressure indirect calorimetry system. The system consists of the following major components: four individually controlled environmental chambers (1.52 W × 1.83 L m each); an air handler (Model Climate-Lab-AA, Parameter Generation & Control, Black Mountain, N.C.); a paramagnetic oxygen analyzer (Model 755A, Rosemount Analytical Inc., La Habra, Calif.); an infrared carbon dioxide analyzer (Model 880A, Rosemount Analytical Inc.); a dew point hygrometer (Model 2001, EG&G Moisture and Humidity Systems, Burlington, Mass.); a barometric pressure sensor (Model CS105, Campbell Scientific Inc., Logan, Utah); four temperature and RH probes, one per chamber (Model HMP35C, Campbell Scientific Inc.); four thermoelectric air mass flowmeters, one per chamber (Model LS-4F, Teledyne Hastings-Raydist, Hampton, Va.); an oil-free diaphragm air pump (Cat. No. H-07061-40, Cole Parmer Instrument Co., Niles, Ill.); and a PC-based environmental control and data acquisition system (ECDAS). The fresh air supply was heated to the desired temperature of the chamber by two electric heater/fan units located in the plenum space of the

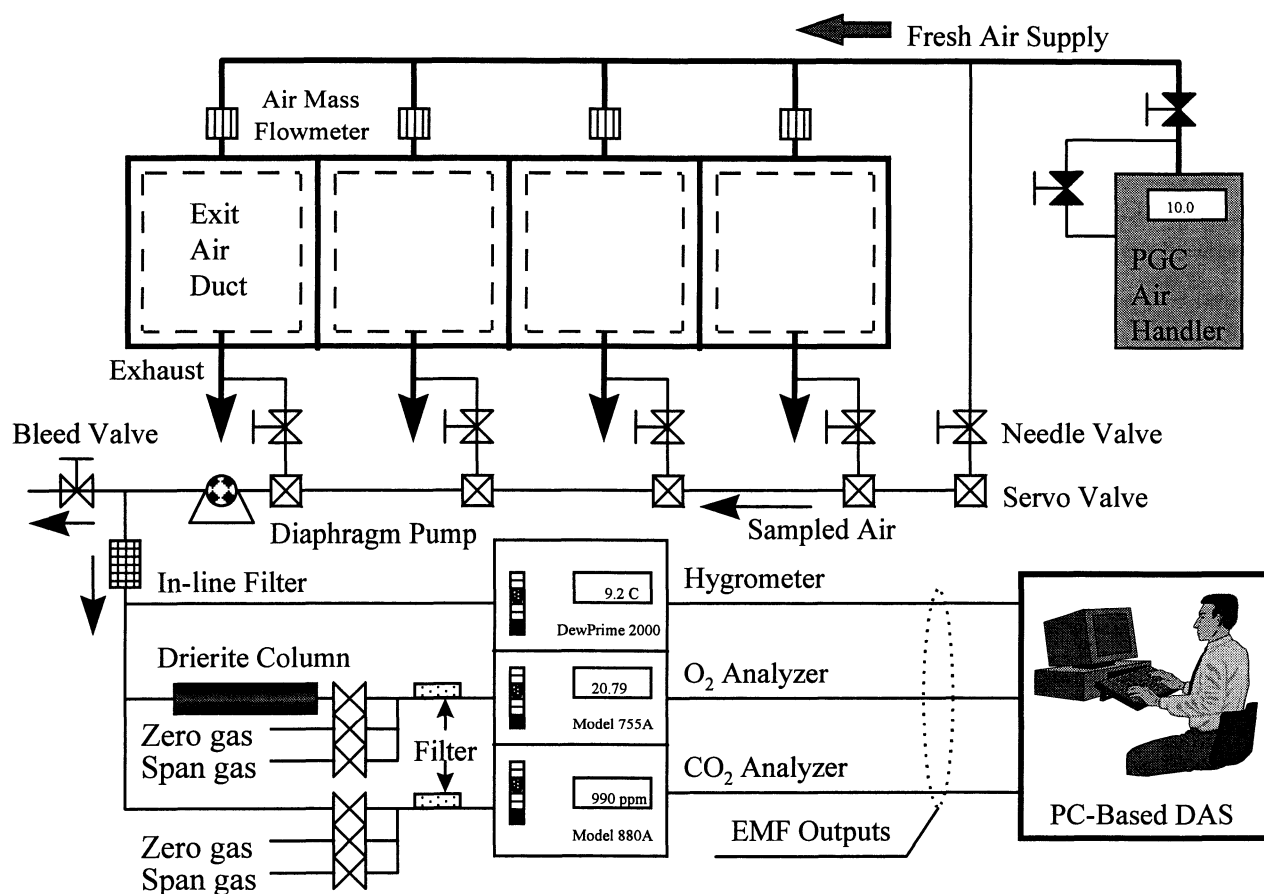


Figure 1—Schematic representation of the Iowa State University indirect calorimeter system.

air inlet and the porous ceiling of the chamber. An air distribution duct was located along the perimeter of the chamber near the chick level to enhance uniform mixing of the outgoing air. Electric heating cords (Cat. No. H-03122-24, Cole Parmer Instrument Co.) and a power controller (Cat. No. H-02604-00, Cole Parmer Instrument Co.) were used to prevent moisture condensation inside the air sample lines (6.4 mm diameter copper tubing). Air sampling was switched by the ECDAS-operated solenoid valves. Air flow rates of the sample lines (one fresh air and four exhaust air) were equalized with needle valves. Each chamber also had a temperature sensor connected to a phone dialer (Model Sensaphone 1104, Phonetics, Inc., Aston, Pa.) capable of calling up to four numbers if chamber temperature was outside the predetermined limits.

Air sampling was performed at 6 min intervals, with the first 5 min used for system purging and stabilization and the last 1 min used for data collection time. During the last minute the ECDAS took measurements of the concerned variables every two seconds and then stored the 30-point averages. The O<sub>2</sub> and CO<sub>2</sub> analyzers were calibrated with primary standard calibration gases (Matheson Gas and Equipment Technology Group, Chicago, Ill.) twice daily throughout the experimental period. The gas analyzers were also checked by combustion of pure ethanol for two hours at the beginning of the experiment (Scott et al., 1983). Furthermore, an error analysis of the measurement instruments indicated a maximum HP measurement error of  $\pm 0.26$  W/chamber. Because the HP magnitude of our study always exceeded 80 W/chamber, the measurement error was anticipated to have rather negligible effects on the results.

#### MEASUREMENTS OF THE ENERGETIC RESPONSES

Total heat production rate (THP, W · kg<sup>-1</sup>) of the chicks was calculated using the short form of Brouwer's equation (1965):

$$\text{THP} = 16.18\text{O}_2 + 5.02\text{CO}_2 \quad (1)$$

where O<sub>2</sub> is the oxygen consumption rate of the chicks (mL · s<sup>-1</sup> · kg<sup>-1</sup>), STPD; CO<sub>2</sub> is the carbon dioxide production rate of the chicks (mL · s<sup>-1</sup> · kg<sup>-1</sup>), STPD; and O<sub>2</sub> and CO<sub>2</sub> were calculated as:

$$\text{O}_2 = V_i (X_i - \alpha X_o) \cdot 10^{-6} \quad (2)$$

$$\text{CO}_2 = V_i (Y_o - \alpha Y_i) \cdot 10^{-6} \quad (3)$$

where V<sub>i</sub> is the inlet air flow rate (mL · s<sup>-1</sup> · kg<sup>-1</sup>), STPD; X<sub>i</sub>, X<sub>o</sub> is the oxygen concentration of the inlet and outlet air, respectively (ppm); Y<sub>i</sub>, Y<sub>o</sub> is the carbon dioxide concentration of the inlet and outlet air, respectively, (ppm); and  $\alpha$  is the correction factor for the outlet air flow rate, calculated as:

$$\alpha = \frac{V_o}{V_i} = \frac{1 - (X_i + Y_i) \cdot 10^{-6}}{1 - (X_o + Y_o) \cdot 10^{-6}} \quad (\text{McLean, 1972}) \quad (4)$$

Moisture production rate (MP, g H<sub>2</sub>O · h<sup>-1</sup> · kg<sup>-1</sup>) was calculated as:

$$\text{MP} = V_i \cdot \rho (\alpha W_o - W_i) \cdot \frac{3600}{1000} \quad (5)$$

where  $\rho$  represents air density (1.293 g · l<sup>-1</sup>); and W<sub>i</sub>, W<sub>o</sub> are the humidity ratio of the inlet and outlet air, respectively, (gH<sub>2</sub>O · gDA<sup>-1</sup>) calculated as:

$$W = 0.62198 \frac{P_w}{P - P_w} \quad (\text{Weiss, 1977}) \quad (6)$$

where P equals barometric pressure of ambient air (kPa); and P<sub>w</sub> is the partial vapor pressure of the inlet or outlet air (kPa) calculated as:

$$P_w = 0.61078e^{\frac{17.2693882 t_{dp}}{t_{dp} + 237.30}} \quad (\text{Weiss, 1977}) \quad (7)$$

where t<sub>dp</sub> is the dew point temperature of the inlet or outlet air (°C). Sensible heat production (SHP, W · kg<sup>-1</sup>) was calculated as the difference between THP and latent heat production (LHP):

$$\text{SHP} = \text{THP} - \text{MP} \cdot h_{fg} \cdot 3600^{-1} \quad (8)$$

where h<sub>fg</sub> is latent heat of water vaporization (2450 J · g<sup>-1</sup>). Respiratory quotient (RQ) was calculated as:

$$\text{RQ} = \frac{\text{CO}_2}{\text{O}_2} \quad (9)$$

The energetic responses of the chicks were calculated as the overall averages over the 50 h exposure period. They were further divided into 12 h period responses over the exposure period to evaluate the effects of exposure duration. Chick body mass (BM) was measured at the beginning and the end of the experiment and was assumed to decrease linearly between the measurements. Body mass loss (BML) was expressed as the percentage of initial body mass, i.e.,  $\Delta \text{BM} / \text{BM}_{(\text{initial})} \cdot 100\%$ . Chick mortality was continuously monitored and was excluded from the determination of total body mass for calculation of the heat and moisture production rates. The response variables were subjected to analysis of variance, regression analysis, and Duncan's multiple mean comparison.

## RESULTS AND DISCUSSION

### EFFECTS OF TEMPERATURE ON CHICK RESPONSES

Table 1 summarizes the average responses of the chicks to the environmental conditions over the 50 h period. To improve readability, graphical presentations of the responses are given in figures 2 and 3. The effects of temperature (t, °C) on MP (g H<sub>2</sub>O · h<sup>-1</sup> · kg<sup>-1</sup>), SHP (W · kg<sup>-1</sup>), THP (W · kg<sup>-1</sup>), BML (% initial BM), and chicks mortality (% placement) were further delineated by the following regression equations:

**Table 1. Energetic and performance responses of neonatal male breeder chicks during a 50 h posthatch exposure to air temperatures of 35, 30, 25, and 20°C and relative humidity of 17%, 22%, 30%, and 40%**

Response Variable		Air Temperature, °C (Relative Humidity, %)			
		35 (17%)	30 (22%)	25 (30%)	20 (40%)
MP	$\bar{x}$	4.6a	4.1b	4.0b	3.8b
	S.E.	0.2	0.1	0.0	0.1
SHP	$\bar{x}$	5.2d	5.7c	6.4b	7.8a
	S.E.	0.2	0.2	0.2	0.3
THP	$\bar{x}$	8.4c	8.5c	9.1b	10.3a
	S.E.	0.3	0.2	0.2	0.3
RQ	$\bar{x}$	0.75a	0.74a	0.75a	0.75a
	S.E.	0.01	0.01	0.01	0.01
IBM	$\bar{x}$	39.8a	39.3a	39.5a	38.8a
	S.E.	0.5	0.4	0.5	0.5
BML	$\bar{x}$	15.9%a	14.9%b	14.4%c	13.5%d
	S.E.	0.3%	0.2%	0.2%	0.2%
Mort.	$\bar{x}$	0.33%b	0.28%b	0.71%ab	1.09%a
	S.E.	0.14%	0.09%	0.16%	0.31%

Row means with different letters are significantly different ( $P < 0.05$ ).

MP - moisture production ( $\text{g H}_2\text{O} \cdot \text{hr}^{-1} \cdot \text{kg}^{-1}$ ).

SHP - sensible heat production ( $\text{W} \cdot \text{kg}^{-1}$ ).

THP - total heat production ( $\text{W} \cdot \text{kg}^{-1}$ ).

RQ - respiratory quotient.

IBM - initial body mass ( $\text{g} \cdot \text{chick}^{-1}$ ).

BML - body mass loss (% initial body mass).

Mort. - mortality (% total placement).

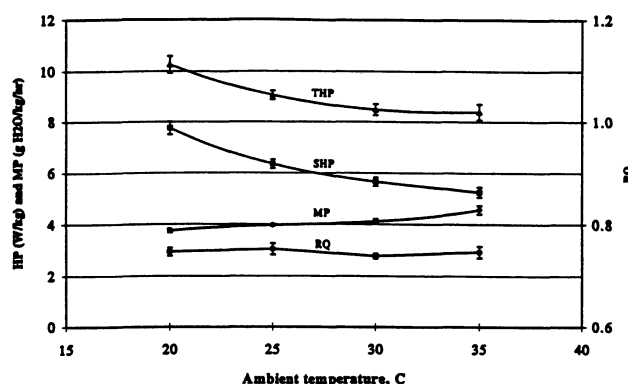
$\bar{x}$  - mean.

S.E. - standard error of the mean.

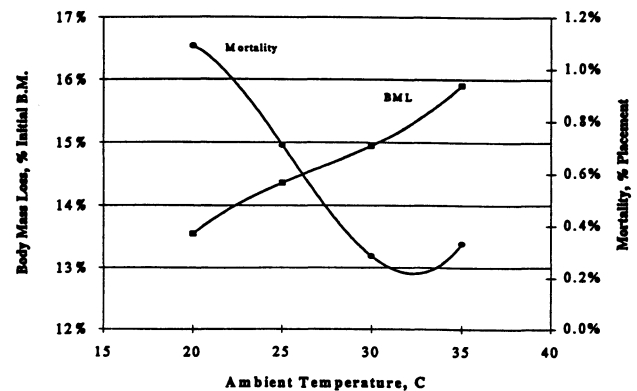
$$\text{MP} = 0.0005t^3 - 0.0379t^2 + 0.9972t - 4.92 \quad (R^2 = 0.999) \quad (10)$$

$$\text{SHP} = -0.0006t^3 + 0.0583t^2 - 1.9437t + 28.31 \quad (R^2 = 0.999) \quad (11)$$

$$\text{THP} = -0.0005t^3 + 0.0480t^2 - 1.6564t + 28.11$$



**Figure 2—Moisture production (MP), sensible heat production (SHP), total heat production (THP), and respiratory quotient (RQ) of neonatal chicks during a 50 h posthatch exposure to air temperatures of 20, 25, 30, and 35°C (the vertical bars are standard errors of the means).**



**Figure 3—Body mass loss (BML) and mortality of neonatal chicks during a 50 h posthatch exposure to air temperatures of 20, 25, 30, and 35°C.**

$$(R^2 = 0.999) \quad (12)$$

$$\text{BML} = (10^{-5}t^3 - 0.0010t^2 + 0.0295t - 0.1438) \cdot 100\% \quad (R^2 = 0.999) \quad (13)$$

$$\text{Mort.} = (10^{-6}t^3 - 0.0003t^2 + 0.0211t - 0.5120) \cdot 100\% \quad (R^2 = 0.999) \quad (14)$$

As shown in table 1 and figure 2, MP remained relatively constant for the temperatures of 20 to 30°C at the level of  $4.0 \text{ g H}_2\text{O} \cdot \text{h}^{-1} \cdot \text{kg}^{-1}$  but increased to  $4.6 \text{ g H}_2\text{O} \cdot \text{h}^{-1} \cdot \text{kg}^{-1}$  at 35°C ( $P < 0.01$ ). The higher MP at 35°C was also associated with a distinctive chick thermoregulatory behavior of spreading on the entire floor space of the container. In comparison, chicks in the other temperature regimens showed various degrees of huddling, with chicks under 20°C huddling the most. MP data of the present study differed considerably from the only available literature data by Mission (1975). MP of the present study, 4.0 to  $4.6 \text{ g H}_2\text{O} \cdot \text{h}^{-1} \cdot \text{kg}^{-1}$ , was much higher than the MP calculated from Mission's data, 1 to  $2 \text{ g H}_2\text{O} \cdot \text{h}^{-1} \cdot \text{kg}^{-1}$ , because MP of the present study included both latent heat loss of the chicks and the evaporation of droppings, whereas MP reported by Mission consisted of only the latent heat loss of the chicks. For practical purposes, MP of the present study should provide more realistic design data.

SHP increased with each step-down in air temperature ( $P < 0.01$ ). The portion of THP dissipated as SHP also increased with decrease in temperature, averaging 62%, 67%, 70%, and 76% at 35, 30, 25, and 20°C, respectively. THP was at a minimum for the temperatures of 30 to 35°C and increased with further decrease in temperature ( $P < 0.01$ ). Based on the concept of least thermoregulatory effort (Bligh and Johnson, 1973; Mount, 1974; Hey, 1974) i.e., minimum THP and MP, the thermal neutrality of the chicks under the present experimental conditions was 30°C. This result was also supported by the lower chick mortality under the 30°C regimen. In fact, according to the regression equation (eq. 14), and as shown in figure 3, the lowest chick mortality would occur at 32°C. Thus, the energetic and mortality data of this study suggest that the optimal environmental temperature would be between 30 and 32°C for the unfed neonatal chicks group-housed in the

excelsior-padded shipping containers. These values, however, were lower than what had been considered as the thermal neutrality of neonatal chicks (35°C) by other researchers (Mission, 1976; Van der Hel et al., 1990). In fact, the chicks under the 35°C regimen were noted to spread on the entire compartment floor, indicating a sign of heat stress. The discrepancy between the present study and literature report might have resulted from differences in stocking density (single chick versus group of chicks), housing condition (with bedding versus without bedding), breed of the chicks, and adaptation of the chicks to the environment.

THP values of the present study generally paralleled the limited literature data. Specifically, the present study showed a THP of 8.5 W · kg<sup>-1</sup> at 30°C, compared with 8.4 W · kg<sup>-1</sup> at 31°C by Van der Hel et al. (1990) and 7.4 W/kg at 30°C by Mission (1975). Furthermore, Kleiber (1961) stated, "Under standard conditions, fasting homeotherms produce daily an average of about 70 kcal of heat per kg<sup>3/4</sup>". The THP of 8.5 W · kg<sup>-1</sup> at 30 to 35°C in this study was equivalent to a daily heat production of 77 kcal/kg<sup>3/4</sup>, which was in good agreement with the cited literature value. Thus, the results reported here confirmed that the use of maintenance heat production (HP<sub>m</sub> = 7 · M<sup>0.75</sup>) largely overestimates the heat production of these neonatal chicks.

No significant difference in RQ was noted among the temperature regimens (P = 0.59). The average RQ of 0.75 fell between the theoretical RQs for metabolism of lipid (0.70) and protein (0.80); although it was slightly higher than those (0.67 ~ 0.74) reported by Mission (1975). BML increased with increasing temperature (P < 0.05). This result paralleled the trend as noted by Van der Hel et al. (1990) who reported a 24-h BML of 8.2% and 9.6% for neonatal chicks held at 31°C and 35°C, respectively. Chick mortality was the highest at 20°C (P < 0.01), presumably a result of hypothermia because day-old chicks act as heterotherms outside their zone of thermoneutrality (Mission, 1975). Similarly, as the temperature exceeded the thermoneutrality, mortality tended to rise (0.33% at 35°C versus 0.28% at 30°C). This trend was consistent with the report by Van der Hel et al (1990) who found a 24 h mortality of 50% when the ambient temperature was 39°C.

#### EFFECTS OF EXPOSURE DURATION ON CHICK RESPONSES

Table 2 contains the summary of energetic responses of the chicks during each of the four 12 h periods. THP was not affected by exposure duration at 30°C or 35°C (P > 0.15), however, THP was significantly lower during the first 12 h period at 20°C and 25°C (P < 0.001). These results agreed with the report by Mission (1976) who demonstrated the dramatic increase in THP of isolated chicks subjected to 20°C from 3.2 W · kg<sup>-1</sup> at 2 h age to 15.4 W · kg<sup>-1</sup> at 24 h age. The drastic increase in THP, or SHP to be exact, for chicks under the cold environments indicated the rapid development of thermoregulatory capability and their effort of maintaining homeothermy. Mission also found that body temperature (T<sub>b</sub>) of the cold-stressed chicks rose from 23.4°C at 2-h age to 32.9°C at 24-h age, with the most drastic change occurring at 4 h age (29.8°C). T<sub>b</sub> was not measured in the present study.

RQ tended to be higher during the second and third periods (13 to 36 h of age), although no significant

**Table 2. Energetic responses of neonatal chicks during different periods of posthatch exposure to air temperatures of 35, 30, 25, and 20°C and relative humidity of 17%, 22%, 30%, and 40%**

Temp.	12 h Period		MP	SHP	THP	RQ
35°C	1 <sup>st</sup>	$\bar{x}$	4.3b	5.1ab	8.1a	0.74a
		S.E.	0.2	0.2	0.3	0.02
	2 <sup>nd</sup>	$\bar{x}$	5.2a	4.8b	8.3a	0.77a
		S.E.	0.2	0.4	0.5	0.06
	3 <sup>rd</sup>	$\bar{x}$	4.1c	5.2ab	8.1a	0.75a
		S.E.	0.3	0.3	0.5	0.02
	4 <sup>th</sup>	$\bar{x}$	4.7b	5.9a	9.1a	0.73a
		S.E.	0.0	0.3	0.3	0.05
30°C	1 <sup>st</sup>	$\bar{x}$	3.9b	5.2a	7.8a	0.72a
		S.E.	0.2	0.1	0.1	0.03
	2 <sup>nd</sup>	$\bar{x}$	4.6a	5.6a	8.6a	0.74a
		S.E.	0.1	0.5	0.7	0.04
	3 <sup>rd</sup>	$\bar{x}$	3.9b	5.8a	8.5a	0.75a
		S.E.	0.2	0.1	0.2	0.01
	4 <sup>th</sup>	$\bar{x}$	4.2ab	6.1a	9.0a	0.74a
		S.E.	0.1	0.2	0.2	0.01
25°C	1 <sup>st</sup>	$\bar{x}$	3.6c	5.3c	7.8d	0.74a
		S.E.	0.1	0.1	0.1	0.01
	2 <sup>nd</sup>	$\bar{x}$	4.4a	6.3b	9.3b	0.78a
		S.E.	0.1	0.2	0.2	0.02
	3 <sup>rd</sup>	$\bar{x}$	3.7bc	6.0b	8.5c	0.77a
		S.E.	0.1	0.3	0.4	0.03
	4 <sup>th</sup>	$\bar{x}$	4.1ab	7.8a	10.6a	0.71a
		S.E.	0.0	0.2	0.2	0.01
20°C	1 <sup>st</sup>	$\bar{x}$	3.6b	6.4c	8.8c	0.74a
		S.E.	0.1	0.1	0.1	0.02
	2 <sup>nd</sup>	$\bar{x}$	4.3a	8.0b	10.9ab	0.75a
		S.E.	0.1	0.4	0.5	0.02
	3 <sup>rd</sup>	$\bar{x}$	3.5b	7.9b	10.3b	0.77a
		S.E.	0.2	0.4	0.4	0.02
	4 <sup>th</sup>	$\bar{x}$	3.7b	9.0a	11.5a	0.74a
		S.E.	0.1	0.4	0.4	0.03

Column means with different letters for each temperature regimen are significantly different (P < 0.05).

MP - moisture production (g H<sub>2</sub>O · h<sup>-1</sup> · kg<sup>-1</sup>).

SHP - sensible heat production (W · kg<sup>-1</sup>).

THP - total heat production (W · kg<sup>-1</sup>).

RQ - respiratory quotient.

$\bar{x}$  - mean.

S.E. - standard error of the mean.

differences were noted. MP was generally the highest during the second period for all the temperature regimens. The exact cause of this outcome was unclear. A probable explanation may be related to the level of chick activities through the adaptation process.

#### CONCLUSIONS

Energetic and performance responses of group-housed neonatal breeder chicks as influenced by environmental conditions were quantified. Equations have been established relating the heat production, moisture production, body mass loss, and mortality of the chicks to the ambient temperatures of 20 to 35°C. The results suggest that unfed, group-housed neonatal chicks have a thermal neutrality of 30 to 32°C. Data reported here provide guidelines for the design and operation of ventilation systems for the transportation of baby chicks.

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